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THE NORTHERN GOSHAWK (*ACCIPITER GENTILIS ATRICAPILLUS*): IS THERE EVIDENCE OF A POPULATION DECLINE?

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Abstract.—I evaluate the claim that Northern Goshawk (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) populations are declining in North America based on a review of the published literature and analyses of demographic data collected on two goshawk populations in New Mexico and Utah. Evidence of a decline would include range contractions, temporal decreases in density, fecundity and/or survival, and/or a negative rate of population change. The goshawk is a former *Category 2* species as determined by the U.S. Fish and Wildlife Service and two petitions have been submitted to list the goshawk as threatened or endangered under the U.S. Endangered Species Act. The petitions claimed that goshawks suffered significant declines in the U.S. because of logging practices and were threatened with extinction as a result of overharvest. There is no evidence of range contractions in western North America and the goshawk's range appears to be expanding (perhaps due to reoccupancy of former range) in the eastern U.S. The majority of data on abundance of breeding pairs indicate that goshawk densities are highly variable spatially and temporally. There is some evidence to suggest that abundance is correlated with food availability. One study claims that goshawk abundance has declined in the past several decades in northern Arizona but the conclusions are based on an inadequate sampling design. Fecundity fluctuates widely but there is no evidence of a negative trend. Fecundity is apparently influenced by a combination of food availability and predation rates. Survival estimates are too limited to analyze for temporal trends and, as a result of insufficient survival data, (λ) have not been estimated for any North American goshawk populations. I conclude there is no strong evidence to support the contention that the goshawk is declining in the U.S. This result can be interpreted either that goshawk populations are not declining or goshawk populations are declining but the declines have not been detected with current sampling techniques (Type 2 error). These two hypotheses cannot be rigorously evaluated with existing published information and will probably not be evaluated in the future with datasets from a single study area because of sampling limitations. To rigorously and objectively evaluate the population trends of the North American goshawk in a timely and cost-effective manner, I recommend a meta-analysis be conducted of all existing published and unpublished datasets.

Key Words: Accipiter gentilis atricapillus; *Northern Goshawk*; *population status*; *forest management*; *endangered species listing.*

El halcón norteño (*Accipiter gentilis atricapillus*): ¿hay pruebas de una reducción de población?

Resumen.—Yo he evaluado la demanda que las poblaciones del (*Accipiter gentilis atricapillus*; de aquí en adelante referido como halcón) se están reduciendo en norte américa basado en un examen de literatura publicada y un análisis de datos demográficos colectados de dos poblaciones de halcón en Nuevo México y Utah. Las pruebas en la reducción deberían incluir contracciones del campo, reducción temporal en densidad, fecundo y/o supervivencia, y/o ritmo negativo de cambio en la población. El halcón fue marcado una especie de Categoría 2 como determinado por el U.S. Fish and Game Service y dos demandas han estado entregadas para designar el halcón como amenazado o en peligro debajo del U.S. Endangered Species Act. Las demandas susieren que los halcones sufrieron reducciones significantes en los Estados Unidos por las reglas que dirigen la cortada de árboles y amenazado con extinción por el resulto de cosechas muy numerosas. No hay ninguna prueba que de las contracciones de campos en el oeste de norte américa y el campo de halcones parece e star haciendo se mas amplio (Tal vez por la ocupación de nuevo de los campos antiguos) en el este de los Estados Unidos. La mayoría de datos sobre la abundancia de parejas de cría indica que la densidad de halcones varia mucho en su espacial y su temporal. Hay pruebas que sugieren que la abundancia esta correlacionada con la disponibilidad de comida. Un estudio susiren que la abundancia se ha reducido en las pasados décadas en el norte de Arizona pero las conclusiones están basadas en un proyecto con insuficiente muestreo. Fluctuaciones de fecundo varían mucho pero no hay ninguna prueba de una tendencia negativa. Fecundo esta aparentemente influido por una combinación de disponibilidad de comida y ritmos de cazar. Estimaciones de supervivencia son muy limitadas para analizar tendencias temporal y, el resultado de los datos insuficiente de supervivencia, no han estado estimados para poblaciones de halcones en norte américa. Yo concluido que no hay pruebas fuertes para soportar el argumento que el halcón se esta reduciendo en los Estados Unidos. Este resultado puede estar interpretado por un lado, que las poblaciones de halcón no están reduciéndose o por otro lado, que las poblaciones se están reduciendo pero las reducciones no han sido descubridas con la técnica de muestreo usada hoy en día (error Pipo 2). Estas dos hipótesis no pueden estar evaluadas con rigor con la información publica que existe y probablemente no va estar evaluada en el futuro con los datos de un área singular de estudio por limitaciones de muestreo. Para poder evaluar rigurosa y objetivamente las tendencias de poblaciones del halcón de norte américa en una manera oportuna y con un precio justo, yo recomiendoque una meta-análisis sec condueida con todos los datos publicados y no-publicados que existen.

[Traducción de Raúl De La Garza, Jr.]

Because the Northern Goshawk (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) often nests (Siders and Kennedy 1996, Squires and Ruggiero 1996) and hunts (Bright-Smith and Mannan 1994) in old-growth or mature forests, potential conflicts between timber harvest and maintenance of viable goshawk populations concerns various publics (Hitt 1992, St. Clair 1992). These concerns have resulted in two petitions to list the goshawk as threatened or endangered in the southwestern (Federal Register 1992a) and western U.S. (Federal Register 1992b, 1996a), and the classification of the goshawk as a Category 2 species (Federal Register 1992a) prior to the elimination of this category by the USDI Fish and Wildlife Service (FWS) in 1996 (Federal Register 1996b). In addition, it is included on the Sensitive Species lists of several USDA, Forest Service (USFS) regions (e.g., Pacific Northwest, Southwest, Intermountain, Rocky Mountain and Alaska) and is a Species of Special Concern in several states (Wisconsin Bureau of Endangered Species 1995, K. Titus pers. comm.). The goshawk has no federal or provincial protection in Canada (World Wildlife Fund Canada Web Site, http://www.wwfcanada.org/speclist.html).

The listing petitions claimed that goshawks had suffered significant declines because of logging practices and that it was under threat of extinction as a result of overharvest. In reviewing a listing petition, the FWS must determine if the petition presents substantial information to warrant a status review. Both of the goshawk petitions were denied by the FWS because the petitions could not document that goshawk populations west of the 100th meridian constitute a distinct population (Federal Register 1996a). Only species, subspecies and, for vertebrates, distinct populations are listable entities under the Endangered Species Act (ESA).

My goal in this paper is to evaluate the claim that goshawk populations have suffered significant declines in the western U.S. I address the following question: is there demographic evidence that goshawk populations are declining? The mark of a species in trouble is not its population abundance or geographic range size at one point in time, but the rate of population decline or range contraction (Caughley and Dunn 1995). A rare or uncommon species can have a stable population or range size (Gaston 1994). Conversely a species in decline can seem relatively common until only a short time before it becomes rare (Caughley and Dunn 1995). Evidence of a decline for both rare and common species would include range contractions, temporal decreases in abundance, fecundity and/or survival and/or a negative rate of population change (λ) (Caughley and Dunn 1995). In this paper I evaluate these lines of evidence by reviewing the available demographic data on goshawks throughout its subspecific range. Although the listing petitions pertain only to the western U.S., I did not restrict my analyses to this region because it is not recognized as a distinct population. Diagnosing causes of decline is irrelevant if there is no evidence that a decline has occurred.

METHODS

This paper summarizes and evaluates the published demographic literature on goshawks and presents results of demographic analyses I have conducted on datasets from New Mexico and Utah. The New Mexico population and study area are described in detail in Siders and Kennedy (1996). The Utah population is located in the Ashley National Forest (ANF) in eastern Utah. During 1991–1995, 42 occupied nest sites were located on the ANF using survey methods recommended by Kennedy and Stahlecker (1993). The ANF is located in the Uinta Mountains and contains approximately 340 000 ha of forested land. The average annual precipitation is 70 cm (range 40–90 cm), with roughly equal precipitation from winter snowfall (November–April) and summer rains (May–October). Lodgepole pine (*Pinus contorta*), spruce-fir (*Picea engelmanni-Abies lasiocarpa*), mixed conifer (includes lodgepole pine, Engelmann spruce and subalpine fir) and ponderosa pine (*Pinus ponderosa*) are the most prevalent forest communities present in the study area. Douglas fir (*Pseudotsuga menziesii*), quaking aspen (*Populus tremuloides*), pinyon-juniper (*Pinus edulis-Juniper osteosperma*), subalpine meadows, sagebrush grasslands and riparian woodlands are also present.

To evaluate changes in ranges, I compared current distribution maps with historic maps and reviewed published accounts of changes in the status of the goshawk at the state and regional scale.

In this review I did not include the migration literature which contains temporal data on counts of migrating goshawks. These data were not included because the relationship between counts of migrants and population abundance is unknown. I agree with Bednarz et al. (1990) and Titus and Fuller (1990) who suggest that population fluctuations in this species may not be adequately monitored by migration counts because goshawk migrations are characterized by irruptive invasions which can mask trends in abundance.

I also did not include results from non-peer-reviewed literature because these datasets have not been subjected to a rigorous scientific evaluation via peer review. Although there is potentially valuable information in this body of literature, the information hasn't been sorted through selectively to separate questionable from reliable information (Bury and Corn 1995).

RESULTS

Range Contractions. Range contractions may be seen in a species' distribution as a partial erosion of the boundary or as a range fragmentation where populations are removed from within the distribution (Caughley and Dunn 1995). In range contraction, the agent of decline can often be identified by knowing something about those factors that determine the boundary of the range (Caughley et al. 1988).

Goshawks are holarctic in distribution, occupying a wide variety of boreal and montane forest habitats throughout North America and northern Mexico (Johnsgard 1990). I assume its breeding range is discontinuous because there are no records of birds breeding in nonforested areas (e.g., prairie regions of Canada and the U.S.). However, its winter range may not be discontinuous because it is observed in nonforested habitats in the winter (P. Kennedy unpubl. data, J. Squires pers. comm.). The northern limit of its distribution is the boundary of boreal forest and tundra habitats. The eastern and western boundaries are the Atlantic and Pacific Oceans, respectively (Palmer 1988, Johnsgard 1990). Factor(s) that limit the southern extent of the range are unknown.

In the eastern U.S., the goshawk may have been more abundant before the extinction (early 1900s) of the Passenger Pigeon (*Ectopistes migratorius*; Bent 1937, Mengel 1965, Brauning 1992) and before the extensive deforestation of this region which reached a peak at the end of the 19th century (McGregor 1988, Foster 1992, Smith et al. 1993, Pimm and Askins 1995). Since 1920, the amount of forested habitat has been increasing throughout the eastern U.S. resulting from the conversion of primarily agricultural landscapes into landscapes dominated by forest (Pimm and Askins 1995). Since this time, there is evidence that eastern goshawk populations may be expanding. Although few records exist before the 20th century, the goshawk was considered a casual or accidental breeding species in the northeast from the late 1800s into the 1950s (Forbush 1927, Bagg and Eliot 1937, Andrle and Carroll 1988, Zeranski and Baptist 1990, Brauning 1992). However, from the 1950s onward, the species' range appears to have expanded and its numbers have increased in many northeastern states (Bull 1974, 1976, Speiser and Bosakowski 1984, Leck 1984, Andrle and Carroll 1988). For example, the first breeding record for Massachusetts was reported by Farley (1923) and there were no reported nests in Connecticut at this time. By 1964 it was a casual nester in northwestern Connecticut and by 1978 at least 19 occupied nest sites were located in this area (Zeranski and Baptist 1990). The first goshawk nest in New Jersey was recorded in 1964 (Speiser and Bosakowski 1984) and it was considered a rare summer resident in New York until the 1950s. Forty-eight breeding sites were located in New York between 1952 and the early 1970s (Bull 1974) and 20 occupied sites were recorded in the Highlands region of northern New Jersey and southeastern New York by the mid-1980s (Leck 1984, Speiser and Bosakowski 1987). In a recent atlas of the breeding birds of New York, the goshawk was recorded as a breeding bird in all but 11 counties (Andrle and Carroll 1988). Andrle and Carroll (1988) compared Bull's (1974) goshawk distribution for New York with their atlas distribution for the state and concluded that the species has expanded its breeding range in New York since the early 1970s.

Table 1. Density of breeding goshawk populations from North America estimated from nest censuses.

YEAR[a]	No. 100 km^{-2}	(N)[b]	FOREST TYPE	LOCATION	SOURCE
1982–85	11	?	Ponderosa pine[c]	Arizona	Crocker-Bedford and Chaney (1988)
1974	3.6	4	Mixed conifer/ Ponderosa pine	Oregon	Reynolds and Wight (1978)
1971–72	7.5	6	Lodgepole pine[d]	Colorado	Shuster (1976)
1984–92	5.7–10.7[e]	6–11	Mixed conifer	California	Woodbridge and Detrich (1994)
1990	10.0	40	Spruce	Yukon	Doyle and Smith (1994)
1992–93	4.6–6.2	4–8	Lodgepole pine	Oregon	DeStefano et al. (1994a)
1992–93	6.6–8.8	6–8	Ponderosa pine/ Mixed conifer	Oregon	DeStefano et al. (1994a)
1992–93	2.6–7.0	3–8	Mixed conifer	Oregon	DeStefano et al. (1994a)
1993	3.8–8.6[e]	4–9	Mixed conifer/ Ponderosa pine	Oregon	DeStefano et al. (1994a)

[a] Time period in which study was conducted. If temporal variation in density is available, the range in annual estimates of density and sample sizes are reported.
[b] N = Number of nests.
[c] Range of values for two different study areas in the same forest type.

Although these data suggest a range expansion (or reoccupancy), this needs to be interpreted cautiously. Increasing populations of goshawks reported in the eastern U.S. could reflect an increased search effort rather than a range expansion. An inability to distinguish these two phenomena has been documented for other poorly detectable raptor species (Stahlecker and Duncan 1996).

Johnsgard (1990) suggested that range contractions might be occurring in the Pacific Northwest and other parts of the west as a result of overharvest of mature forests. However, the goshawk's western distribution as described by Bent (1937) has not changed (Palmer 1988, Johnsgard 1990). In addition, there are no current reports of local population extirpation in any portion of the goshawk's geographic range.

Patterns of Abundance. Range size and abundance are correlated variables. Within particular taxa and geographical regions, species with large ranges tend to have greater local abundances at sites where they occur than do species that are more restricted geographically (Gaston 1994, Lawton 1995). Based on these zoogeographic patterns, the goshawk, which is widely distributed across North America, is predicted to be more abundant locally than comparably-sized forest-dwelling species with more restricted ranges such as the Red-shouldered Hawk (*Buteo lineatus*). Hejl et al. (1995) recently classified the goshawk as a common breeder in the majority (6 of 8 types) of forest types in the Rocky Mountains.

Breeding density has been estimated for several North American populations of goshawks. Two methods based on searches for occupied nests have been used to estimate these densities: counts of breeding pairs and distribution of nearest-neighbor distances. Both methods are based on the unlikely (and untested) assumption that all nests have been located in the survey area (Gould and Fuller 1995). Comparability of these estimates also is complicated by use of different survey techniques among studies (Siders and Kennedy 1996).

Mean nearest-neighbor distances range from 3.0–5.6 km [Oregon, 1974, N = 4, range = 2.4–8.4 (Reynolds and Wight 1978); California, 1984–1992, N = 21, range = 1.3–6.1 (Woodbridge and Detrich 1994); Arizona, 1992, N = 59, range = 2.4–8.4 (Reynolds et al. 1994)]. Nest densities have been estimated to range from 2.6–11 nests per 100 km^{-2} (Table 1). High densities of 10–11 nests per 100 km^{-2} have been recently reported in three study areas: Arizona, California and the Yukon (Table 1).

In addition to the extensive spatial variation described above, breeding densities can vary annually. Although densities did not vary during two years in one study area in Colorado (Shuster 1976), in three study areas in Oregon, densities varied from 33–270% during 2 yr (DeStefano et al. 1994a; Table 1). The Bly study area censused by DeStefano et al. (1994a) in 1993 was the same study area censused by Reynolds and Wight (1978) in 1974. The number of occupied nest sites located on this study area ($N = 4$) did not change over the 21-yr period and thus densities were equivalent (3.6 in 1974 and 3.8 in 1993; Table 1; variation due to slightly more acreage censused in 1974).

Two studies have attempted to quantify population trends in goshawk populations using data from breeding populations (Crocker-Bedford 1990, Doyle and Smith 1994). Crocker-Bedford (1990) was the first person to suggest in the scientific literature that goshawk populations were declining due to overharvest of their forested habitat. This idea is important and it needed to be published. However, his study does not do an adequate job of rigorously evaluating this hypothesis. Crocker-Bedford claims that the goshawk population on the North Kaibab Ranger District of the Kaibab National Forest in Arizona declined from an estimated 260 nesting pairs to approximately 60 pairs by 1988. This estimated decline is not based on temporal variation in densities. Rather, it is based on a comparison of densities estimated during the 1985–87 breeding seasons between areas harvested during two different time periods. He compared densities from areas lightly harvested in the 1950s and 1960s (controls) to areas that were more intensively harvested from 1970–85 (treatments). Crocker-Bedford estimated densities by censusing the number of nest structures found per unit area and multiplying the number of structures by the ratio of nests to breeding pairs. He did not identify how he differentiated nest structures of different species such as Cooper's Hawks (*Accipiter cooperii*) and Red-tailed Hawks (*Buteo jamaicensis*) that nest in similar habitats and build similar structures (Preston and Beane 1993, Siders and Kennedy 1996). Although his data suggest more nest structures can be found in lightly harvested areas as compared to heavily harvested areas, his inference from this dataset to estimating rate of population change is unwarranted. The relationship between number of nest structures and number of goshawk breeding territories is unknown and the assumption that spatial variation in nest structure density reflects temporal variation in nest structure density is not supported by any data and is probably unjustified biologically.

Doyle and Smith (1994) examined variations in an index of goshawk abundance (intensive surveys of breeding pairs combined with year-round sightings) from 1987–93 in the boreal forest in southwest Yukon, Canada. Although these data were not analyzed statistically, the abundance index changed by more than a factor of four over a 2-yr period. They also monitored hare abundance from 1987–93 and concluded that changes in goshawk abundance probably resulted from cyclic changes in hare densities. During periods of high hare density, goshawks were abundant on the study area all years and hares accounted for over 55% of the total prey biomass. As hare populations declined, goshawks became more nomadic and virtually disappeared in the winter. They located 40 pr in a 400 km^2 area during 1990, a peak prey year. No successful breeding was recorded in this same area during 1992 when hare numbers were lowest.

Indirect evidence of a decline in abundance might also be indicated by a loss of territories (defined below) over time. However, evidence suggests that more territories are being located annually as search effort increases. For example, in the southwestern U.S., few locations of nesting goshawks were known prior to 1990 and no systematic effort was made to monitor known nest sites. After the development of a standardized survey technique by Kennedy and Stahlecker (1993), efforts by the USFS to inventory proposed timber sale areas began on many of the national forests in this region. Since 1991, the annual number of nesting locations discovered has risen steadily (Fletcher and Sheppard 1992). In northcentral New Mexico, 39 goshawk territories were located during 1984–95 (Siders and Kennedy 1996). An average of 3.3 new territories (SD = 4.9) have been located every year since 1984 and only one territory has been abandoned since it was located. An average of eight new territories (SD = 5.1, $N = 42$) has been located every year from 1991–95 in the Uinta Mountains, Utah. Territory abandonments have not been documented in this study area. Rates of territory discovery and abandonment are not available for other study areas with long-term (>5 yr) datasets.

Reproductive Patterns. Typically the reproductive patterns of raptors are subdivided into three components, each of which is estimated separately: occupancy rates, nest success and productivity. Terminology defined by Postupalsky (1974), Steenhof and Kochert (1982) and Woodbridge and Detrich (1994) was used to define these components.

Occupancy rates. An occupied territory is defined as a cluster of nest stands exhibiting regular use by a minimum of one adult goshawk during the breeding season. Occupancy rate is defined as the proportion of known territories that are occupied. Similar to many long-lived species (Newton 1979, 1991, Marti 1994), not all goshawks produce offspring annually. In three studies with a minimum of four yr of data, average occupancy rates/territory were remarkably similar: New Mexico = 74.4% (SD = 30.5%, N = 22); Utah = 74.7% (SD = 28.7%, N = 26) and California = 74% (SD = 5.5%, N = 26, Woodbridge and Detrich 1994). The sample sizes in each study were comparable and the number of monitored territories increased over time in each study. Territories with <4 yr of data were not included in these statistics. The New Mexico dataset included a maximum of 22 territories with 4–11 yr of occupancy data per nest. The Utah dataset included a maximum of 26 territories with 4–7 yr of occupancy data per nest and the California dataset included a maximum of 26 territories with 5–9 yr of data per nest (Woodbridge and Detrich 1994).

Interstudy comparisons of occupancy rates need to be done cautiously because occupancy rate is probably positively correlated with the amount of effort expended to determine territory status. Level of effort was comparable among the three studies where all territories were checked a minimum of 2–3 times each year and most territories were visited numerous times each season (B. Woodbridge pers. comm.). In New Mexico and Utah, an area with a radius 0.7–1.0 km (the postfledging area as defined by Kennedy et al. 1994) surrounding the previously occupied nest was intensively surveyed using broadcast vocalizations (Kennedy and Stahlecker 1993) and visual searches of all individual trees. Woodbridge and Detrich (1994) used the same searching methods but their search area was larger, a 1.6 km radius surrounding the previously occupied nests.

Doyle and Smith (1994) found that the number of territorial pairs (range 0–8) of goshawks detected changed with hare densities. When hare densities were low, no goshawks were detected as breeding birds. At maximum hare densities, eight territorial pairs were recorded. The variation in occupancy rates in other studies could be a function of prey availability during the winter and courtship.

Nest success. I define nest success as the proportion of occupied territories that produce at least one young of bandable age. Average nest success varies from 0.47–0.94 (Table 2). Annual variation in nest success is high; in New Mexico over a 12-yr period it varied from complete nesting failure to 100% success in two successive years (Fig. 1). In Utah, over a 7-yr period it varied from 0.33–0.91 (Fig. 1). To explore the possibility of a decline in nesting success over time, I evaluated the temporal variation in these nest-success estimates using linear regression (Regression Data Analysis Procedure—Microsoft EXCEL Ver. 7.0 for Microsoft Windows 95). There was no evidence of a negative correlation between time and nest success in New Mexico (R^2 = 0.20, P = 0.14, N = 12 yr) or Utah (R^2 = 0.03, P = 0.694, N = 7 yr) (Fig. 1). It is interesting to note that the temporal patterns in nest success between 1990–95 are qualitatively similar for both study areas.

In Arizona during 1991–92, Reynolds et al. (1994) found that 3% (N = 3) of 98 nest attempts did not lay eggs or failed in early incubation, 6% (N = 6) of the clutches were lost later in incubation and 6% (N = 6) of the nests failed during the nestling period. Possible causes of nest failure were not discussed. In New Mexico, over a 12-yr period, out of 122 nest attempts, 8% (N = 10) failed during incubation from predation and unknown causes and 8% (N = 10) failed during the nestling period from predation, disease, harvest by falconers or inclement weather.

Productivity. I define productivity as the mean number of bandable young produced per occupied territory. Productivity of North American goshawks ranges from 0.0–2.8. The lowest estimate of average productivity (0.0) are from the Yukon and the highest average estimates (2.8) are from Nevada and the Yukon (Table 2). In the Yukon, productivity appeared to increase with hare abundance (Doyle and Smith 1994). Pairs breeding at the hare peak fledged 2.8 young per pair. In two low-hare years they reported zero productivity.

To explore the possibility of a decline in productivity over time, I evaluated the temporal variation in this variable for New Mexico and Utah using linear regression (Regression Data Analysis Procedure—Microsoft EXCEL Ver. 7.0 for Microsoft Windows 95). There was no evidence of a negative correlation between time and productivity in New Mexico (R^2 = 0.05, P = 0.49, N = 12 yr) and Utah (R^2 = 0.07, P = 0.56, N = 7 yr) (Fig. 2). Similar to nest success, the pattern in productivity between the two study areas is qualitatively similar during 1990–95.

Survival Patterns. *Nestling survival.* Nestling survival rates have been estimated in two studies in

Table 2. Average nest success and productivity of goshawks in North America.

LOCATION	YEARS (NO. NESTS)	NEST SUCCESS[a] (SD)	MEAN PRODUCTIVITY[b] (SD)	SOURCE
Arizona	1985–87 (19)[c]	NA[d]	2.1 (NA)	Crocker-Bedford (1990)
	1985–87 (12)		0.5 (NA)	
Arizona[e]	1991 (37)	0.94	2.0 (0.83)	Reynolds et al. (1994)
	1992 (61)	0.83	1.7 (1.08)	
California	1984–92 (28)	0.87 (NA)	1.93 (0–4)[f]	Woodbridge and Detrich (1994)
Nevada	1991 (14)	NA	1.2 (NA)	Younk and Bechard (1994)
	1992 (22)		2.8 (NA)	
New Mexico	1984–95 (4–31)[g]	0.47 (0.34)	0.94 (0.64)	This study
E. Oregon	1969–74 (48)	0.94	1.7 (0.76)	Reynolds and Wight (1978)
E. Oregon	1992 (6–10)[h]	NA	1.0–2.2 (0.57–0.75)	DeStefano et al. (1994a)
	1993 (3–7)[i]		0.3–2.2 (0.72–1.08)	
E. Oregon	1992 (12)	0.83	1.2 (NA)	Bull and Hohmann (1994)
Utah	1989–95 (3–42)[g]	0.59 (0.21)	1.22 (0.3)	This study
Yukon	1989 (3)	NA	1.3 (0.88)	Doyle and Smith (1994)
	1990 (8)		2.8 (0.57)	
	1991 (7)		1.3 (0.47)	
	1992 (1)		0.0	

[a] Nest success is defined as the proportion of occupied territories that produce at least one young of bandable age. See text for definition of territory.

[b] Productivity is the mean number of young of bandable age per occupied territory.

[c] Study included 19 control territories and 12 treatment territories. See text for more details.

[d] NA = not available.

[e] Same study area as Crocker-Bedford (1990).

[f] Range in one study area.

[g] Number of territories increased over time.

[h] Range from three study areas.

[i] Range from five study areas.

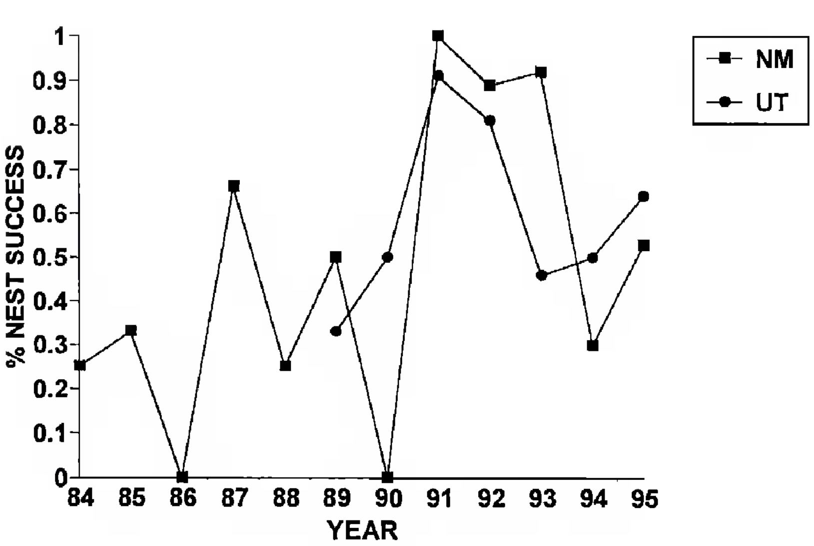

Figure 1. Temporal patterns in nest success of two goshawk populations: northcentral New Mexico and eastern Utah. Yearly sample sizes for New Mexico are 4, 3, 3, 3, 4, 2, 3, 18, 19, 24, 20 and 19 occupied territories, respectively. Yearly sample sizes for Utah are 3, 2, 11, 27, 26, 22 and 25 occupied territories, respectively.

North America. Reynolds and Wight (1972) reported a fledgling success rate (number of young fledged/number of young hatched) of 72% (28% mortality rate) for 11 successful nests monitored from 1969–74 in Oregon. This estimate is probably underestimated because unsuccessful nests are not included. In addition, this estimate was based on data pooled over 1969–74 so temporal variation in nestling mortality was not estimated. Ward and Kennedy (1996) investigated the effect of food supplementation on juvenile survival during 1992–93. In 1992, survival of birds provided with supplemental food (treatment) averaged 80% (N = 15 nestlings) and was not significantly different from the 100% survival rate of unfed (control) birds (N = 16 nestlings). In 1993, treatment survival was significantly higher ($\bar{x}$ = 90%, N = 10 nestlings) than the survival of unfed birds ($\bar{x}$ = 37%, N = 8 nestlings). These data suggest that nestling mortality can vary annually from 0–63%. No data are available to determine long-term temporal trends in nestling mortality.

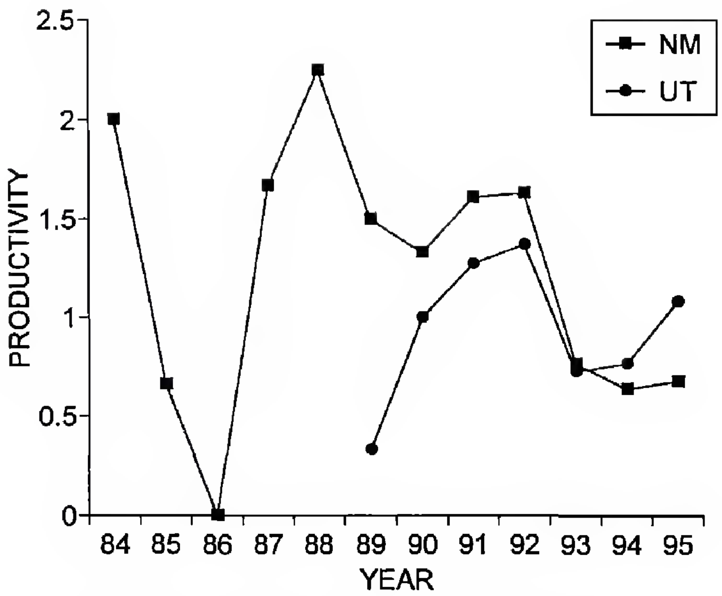

Figure 2. Temporal patterns in productivity of two goshawk populations: northcentral New Mexico and eastern Utah. Yearly sample sizes for New Mexico are 4, 3, 3, 3, 4, 2, 3, 18, 19, 24, 20 and 19 occupied territories, respectively. Yearly sample sizes for Utah are 3, 2, 11, 27, 26, 22 and 25 occupied territories, respectively.

Ward and Kennedy's (1996) study suggest that nestling survival rates are influenced by both food availability and predation rates. They found that no juveniles died of starvation and the majority died of predation or disease. Based on behavioral observations of the adults they suggest that food limitation can result in higher predation rates on nestlings because females must allocate more time to foraging and less time to nest defense.

Juvenile survival. Using radiotelemetry, Ward and Kennedy (1996) estimated juvenile survival rates from fledging until the juveniles were approximately 5.5 mo of age in 1992 (telemetry monitoring ceased in mid-October) and from fledging until the juveniles were approximately 7-mo old in 1993 (telemetry monitoring ceased at the end of November). These survival rates include the fledging-dependency period (approximately 50 d) and 2.5–4 mo after independence (Ward 1994). During 1992–93, treatment survival was not significantly higher than control survival; overall survival varied from 67–100%. No estimates of annual juvenile mortality are available for North America and temporal trends in this parameter are unknown.

Adult survival. Adult survival estimates are available from two studies in North America: northern California (DeStefano et al. 1994b) and northern New Mexico (this study). Both studies estimated survival using mark-recapture/resight methodology (Lebreton et al. 1992, Gould and Fuller 1995). Both studies used program RELEASE for data summarization and goodness-of-fit tests (Burnham et al. 1987). Goodness-of-fit tests examine the data with a series of χ^2 tests to determine if the data fit the general capture-recapture model (Burnham et al. 1987, DeStefano et al. 1994b). DeStefano et al. (1994b) used program SURGE (Lebreton et al. 1992) to derive point estimates and variances of survival. I used program MARK (G. White unpubl. software) to develop the same estimates for the New Mexico population. Both programs use Cormack-Jolly-Seber models to estimate parameters. In these models ϕ = survival and p = probability of resighting. MARK provides the same capabilities as SURGE but it has an improved user-interface and allows the user to test additional models not available in SURGE (G. White pers. comm.).

DeStefano et al. (1994b) examined eight models and I examined 12 models, where ϕ and p are assumed to vary among years (ϕ_t, p_t) and between sexes (ϕ_s, p_s) and all possible interactions of sex and time were evaluated. Both studies used Akaike's Information Criteria (AIC) to select the model that best fit the data with the fewest number of parameters and was still biologically reasonable (Lebreton et al. 1992). AIC is a quantitative method of selecting the "best" data-driven model among a set of competing models. AIC selects a model that balances bias and variance tradeoffs (Lebreton et al. 1992).

The New Mexico estimates were based on capture-recapture/resighting histories on 45 adult breeding goshawks that were trapped and banded from 1984–95 (Kennedy et al. 1994). This dataset fit the general capture-recapture model (χ^2 = 3.69, P = 0.72). The two models $[\phi_{.}, p_{s+t})(\phi_{.}, p_{s*t})]$ with the lowest AIC values (Table 3) indicated there was no evidence that survival varied by sex or time and recapture probabilities varied by sex (higher for females because they were sighted more frequently at the nest) and year (increased efficiency of resighting with time). It is likely that survival does vary by sex and year and my inability to detect this variation is a result of small sample sizes and low resighting probabilities. Annual adult survival in this study area during this time period is estimated to be 0.86 ± 0.09. Because recapture probabilities varied by sex and year and sample sizes were small, the precision in this estimate is low: 95% CI = 0.60–0.96. In addition, these estimates may be low because some marked birds may have emigrated from the study area.

DeStefano et al. (1994b) estimated survival with

Table 3. Capture-recapture models used to estimate survival of adult, breeding northern goshawks in north-central New Mexico, 1984–95.

Model	No. Parameters	Deviance	AIC[a]
General model			
($\phi_., p_.$)[b]	2	55.346	137.001
Time-specific models			
($\phi_., p_t$)	5	48.748	136.403
Sex-specific models			
(ϕ_s, p_s)	4	48.707	134.362
($\phi_., p_s$)	3	50.709	134.364
Time- and sex-specific models			
($\phi_., p_{s+t}$)	6	40.283	129.937
($\phi_., p_{s*t}$)	9	35.669	131.324
(ϕ_s, p_{s+t})	7	40.278	131.932
(ϕ_t, p_{s+t})	8	38.359	132.014
(ϕ_s, p_t)	6	43.152	132.807
(ϕ_t, p_{s*t})	11	33.854	133.509
(ϕ_{s+t}, p_{s+t})	9	37.861	133.516
(ϕ_{s*t}, p_t)	11	37.593	137.247
(ϕ_{s*t}, p_{s*t})	12	32.084	133.739

[a] AIC = Akaike's Information Criteria (AIC = [2 × No. Parameters] + Deviance).

[b] ϕ = survival rate and p = recapture probability.

a larger dataset ($N = 95$) over a comparable time period (1983–92). In their analysis, the model (ϕ_{st}, $p_.$) had the lowest AIC value indicating that survival varied among years and by sex. Female survival was estimated to vary annually from 0.35–0.93. Male survival was estimated to vary from 0.20–0.94. However, the overall fit of the California data to the model was inadequate so their survival estimates must be interpreted cautiously. As the authors indicated, this lack of fit is probably a function of three factors: sample size, high rates of breeding dispersal resulting in an underestimation of survival and methodological constraints (only resighted birds at successful nests).

Although the results of these two studies provide imprecise point estimates of goshawk survival in North America, they are not adequate to evaluate temporal trends in survival. As noted by DeStefano et al. (1994b), temporal trends in goshawk survival can only be estimated with capture-recapture techniques if the estimates are based on large numbers of marked birds (>100), high resighting rates and at least five yr of data. This will require large study areas and large field crews. In addition, this technique is not appropriate if breeding dispersal outside of the study area is common.

Rate of Population Change. Because of the aforementioned insufficient survival information, rates of population change (λ) are not available for any North American goshawk population.

CONCLUSIONS

Based on an analysis of nesting records, there is no evidence of range contractions in western North America and the goshawk's range appears to be expanding (or reoccupied) in the eastern U.S. Populations may have been lost in the west as a result of deforestation but these losses have not been recorded in the published literature. A detailed analysis of 20th century deforestation and reforestation rates throughout North America would provide additional indirect information on potential temporal changes in the goshawk's range.

The majority of data on abundance of breeding pairs indicate that goshawk densities are highly variable spatially and temporally. There is some evidence to suggest that abundance is correlated with food availability. Breeding densities in one study area in Oregon were estimated during 1971 and 1993, and these two estimates were identical. Crocker-Bedford (1990) has claimed that goshawk abundance has declined in the past several decades in northern Arizona but his conclusions are suspect for reasons detailed earlier in this paper.

No declines in fecundity have been recorded and fecundity fluctuates widely. Results from several studies indicate that fecundity is influenced by a combination of food availability and predation rates. Survival data are too limited to analyze for temporal trends and as a result of insufficient survival data, λ has not been estimated for any North American goshawk population.

I conclude there is no evidence to support the hypothesis that goshawk populations are declining. This result can be interpreted in two ways: (1) goshawk populations are not declining; or (2) goshawk populations are declining but the declines have not been detected with current sampling techniques (Type 2 error). If the first interpretation is correct then goshawk populations are not declining and thus, it should not be listed as threatened under the ESA. The lack of demographic evidence to support a decline corroborates the results of the FWS analyses of both listing petitions (insufficient evidence to support a status review).

These results also suggest that the national concern for goshawk populations may not be driven by concerns for goshawk viability but is motivated by concerns of overharvest of old-growth forests. Although the concerns about overharvest of forested communities is certainly justifiable, listing a species for which there is no evidence of a population decline would be a misuse of that legislation and could greatly erode the credibility of the ESA. In addition, it would impact the recovery process of truly threatened and endangered (T&E) species by diverting the limited resources available for T&E species conservation to goshawk recovery.

Alternatively, it is possible the goshawk is declining and the decline is going undetected because of the paucity of data on temporal trends in mortality and abundance. Typical of many raptor studies, goshawk research has focused on quantifying trends in reproduction, not mortality or abundance. This is because reproductive data are easier and less expensive to collect than abundance or mortality data. Obtaining estimates of abundance and mortality with reasonable levels of precision requires large sample sizes of goshawks and long-term sampling (>5 yr). Unbiased estimates of goshawk abundance also require use of randomized or stratified study designs where all forested communities (not just old-growth forests) are surveyed for goshawk presence (Siders and Kennedy 1996, Squires and Ruggiero 1996).

Because of the low detectability of the goshawk and the resulting analysis problems associated with limited sample sizes, it is unlikely that data collected by any single investigator will be sufficient to determine whether or not goshawk populations are declining. It is clear that the information currently available to the agencies concerning goshawk population trends and demographic parameters is insufficient to diagnose population declines. However, I think goshawk population trends could be diagnosed with a meta-analysis of all existing datasets.

Meta-analysis is a method of integrating statistical results from independent studies. It provides both a rigorous, quantitative analysis of cumulative evidence and a practical method of systematically and objectively developing and examining a large dataset based on pooled observations (VanderWerf 1992). Meta-analysis is frequently used in the biomedical field (Mann 1990) but rarely has it been applied in ecology and conservation biology (Järvinen 1991, VanderWerf 1992, Burnham et al. 1996, Forsman et al. 1996).

If goshawk researchers are willing to collaborate, a meta-analysis could be conducted to evaluate the existing demographic datasets on the goshawk. The main objective of this meta-analysis would be to conduct a rigorous and objective analysis of the empirical data available on the North American populations of this species to determine the population trends of the North American goshawk. The results of this analysis would provide an objective analysis of existing information for federal and state agencies involved with goshawk management and listing decisions and identify future goshawk research needs, if the aforementioned questions cannot be answered definitively with existing datasets.

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